

TITLE OF THE INVENTION  
PATTERN INSPECTION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the  
benefit of priority from the prior Japanese Patent  
Application No. 2002-240858, filed August 21, 2002, the  
entire contents of which are incorporated herein by  
reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to a pattern  
inspection apparatus for inspecting pattern defects of  
a plate to be inspected where micropatterns are formed,  
e.g., a photomask used in a manufacturing process of a  
15 semiconductor integrated circuit.

2. Description of the Related Art

A pattern size of a large-scale-integrated circuit  
(LSI) has been reduced more and more in recent years,  
and it is expected that products having minimum line  
20 widths of 0.1  $\mu\text{m}$  or lower will be mass-produced in the  
near future. Such downsizing has been accompanied by  
an extremely small defect dimension to be detected,  
which makes it essential to develop a pattern  
inspection apparatus for inspecting patterns of an LSI,  
25 and pattern defects of a transfer mask used for LSI  
manufacturing.

Conventional pattern inspection methods are mainly

classified into die-to-die comparison, in which two chips of similarly written patterns are observed by different detectors, and a difference between the two is detected by comparison based on a defect detection algorithm, and die-to-database comparison, in which a chip of a written pattern is observed by a detector, which is then compared with designed pattern data by a defect detection algorithm to detect a defect.

In the die-to-die comparison method, since the two chips of the similarly written patterns are observed, there is a drawback of impossible detection of the defects if similar defects are present. On the other hand, in the case of the die-to-database method, even if no such problem occurs because of the comparison with the designed pattern data, there is a drawback of noncoincidence between detected image data and reference pattern image data, which causes false defects. Consequently, highly sensitive and highly accurate inspection is difficult.

Thus, the die-to-die comparison method and the die-to-database comparison method have advantages and disadvantages, and there is a demand for an inspection apparatus which can combine these methods well. However, in the case of combining the two methods, the following problems occur, especially when the die-to-die comparison method is used.

That is, since there is variance in dimensions of

dicing portions between chips on a mask to be inspected and there is no repeated pattern in a peripheral pattern portion, it is impossible to carry out a simple step of obtaining a dimension of one chip at equal  
5 distribution. Thus, it is necessary to teach a repetition start position of the chip to the apparatus by an operator's operation based on an instruction manual. At present, by using feature pattern shapes, the operator visually verifies a start position, a  
10 finish position etc., of each chip. Consequently, operation mistakes by the operator and setting variance easily occur, which leads to a problem of reduction in inspection accuracy.

Therefore, there is a demand for a pattern  
15 inspection apparatus which can prevent operation mistakes by the operator and setting variance in the die-to-die comparison method, and improve operability and inspection accuracy.

#### BRIEF SUMMARY OF THE INVENTION

20 A pattern inspection apparatus of the present invention comprises:

imaging optics which forms an optical image of a pattern formed on a plate to be inspected based on designed pattern data;

25 a detected pattern data generator which detects the optical image to generate detected pattern data;

a reference pattern data generator which generates

first reference pattern data regarding the detected pattern data from the designed pattern data;

5 a first comparator which compares the detected pattern data with the first reference pattern data to detect a defect of the pattern formed on the plate;

a first memory which, when there are a plurality of repeated pattern areas on the plate, stores pattern data obtained by detecting an inspection area, which is one of the plurality of repeated pattern areas, as  
10 second reference pattern data;

a second comparator which compares the detected pattern data with the second pattern data to detect the defect of the pattern formed on the plate; and

15 a computer which reads an arrangement, a number, a dimension and a repeated pitch of the plurality of repeated pattern areas from the designed pattern data, and stores the inspection area as a basis of the second reference pattern data.

20 In the reference pattern data generator, detected pattern data within an arbitrary range may be used in place of the designed pattern data to generate first reference pattern data regarding the detected pattern data.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

25 FIG. 1 is a schematic view of a pattern inspection apparatus according to a first embodiment.

FIG. 2 is a block diagram showing a configuration

of a comparator used in the pattern inspection apparatus of FIG. 1.

FIG. 3 is a plan view schematically showing a configuration of a pattern written on an inspection mask.

FIG. 4 is a conceptual view showing a hierarchical structure of designed pattern data.

FIG. 5 is a conceptual view showing a flow of a preprocessing step for extracting a repeated description.

FIG. 6 is a view showing a configuration example of an inspection condition file.

FIG. 7 is a time chart explaining an inspection step for one stripe to be inspected.

FIG. 8 is another time chart explaining an inspection step for one stripe to be inspected.

FIG. 9 is another time chart explaining an inspection step for one stripe to be inspected.

FIG. 10 is a view showing a stripe example of a pattern written on a mask to be inspected according to a second embodiment.

FIG. 11 is a schematic view showing a pattern configuration where only one chip is arranged on one mask according to a third embodiment.

FIG. 12 is a conceptual view showing a figure code example.

FIG. 13 is a block diagram showing a configuration

of a data generation circuit used according to a fourth embodiment.

FIG. 14 is a block diagram showing a main part configuration of a fifth embodiment.

5        FIG. 15 is a schematic view of a pattern inspection apparatus according to a modification of the first embodiment.

#### DETAILED DESCRIPTION OF THE INVENTION

Next, the embodiments of the present invention  
10 will be described with reference to the accompanying drawings.

##### (First Embodiment)

FIG. 1 is a schematic configurational view showing a pattern inspection apparatus according to a first  
15 embodiment of the present invention.

In this apparatus, a microscope or the like is used to enlarge a pattern formed on a photomask (plate to be inspected) 11, the enlarged pattern is divided into narrow stripes of about 200  $\mu\text{m}$  in width, and  
20 inspection is carried out by continuously scanning the stripes (actually a table is continuously moved).

The photomask 11 is placed on an XY $\theta$  table 12, and moved in XY $\theta$  directions by a movement of the table 12. A light source 13 is arranged above the mask 11, and  
25 the pattern formed on the mask 11 is illuminated by the light source 13. Light transmitted through the mask 11 is made incident through magnification optics 14 on

a photodiode array 15. Thus, an optical image of the pattern of the mask 11 is formed on the photodiode array 15.

5 The optical image of the pattern formed on the photodiode array 15 is subjected to photoelectric conversion by the photodiode array 15, and further subjected to A/D conversion by a detected pattern data generation circuit 16. Detected pattern data outputted from the detected pattern data generation circuit 16 is  
10 sent together with data indicating a position of the photomask 12 on the XYθ table 12 outputted from a positional data acquisition circuit 17 to a comparator 18.

On the other hand, designed pattern data used to  
15 form the pattern on the photomask 11 is read from a magnetic storage disk 19 to a bit pattern data generation circuit 21 by a computer 20. At the bit pattern data generation circuit 21, the designed pattern data is converted into bit pattern data,  
20 which is sent to a reference pattern data generation circuit 22.

The bit pattern data is obtained by converting figure data into 2-dimensional bit image pattern data.

At the reference pattern data generation  
25 circuit 22, multivalued reference pattern data is generated by executing filter processing for the figure bit pattern data sent from the bit pattern data

generation circuit 21. The filter processing at the reference pattern data generation circuit 22 simulates resolution characteristics of the magnification optics 14, aperture effects of the photodiode array 15, and blurs caused by interference or the like between adjacent pixels. That is, since the detected pattern data obtained from the detected pattern data generation circuit 16 is in such a blur generated state, the designed pattern data is subjected to filter processing to match the detected pattern data.

The comparator 18 compares the detected pattern data with reference pattern data in accordance with an algorithm, and determines presence of a defect if there is no coincidence between the data.

According to the embodiment, in addition to the aforementioned configuration, a route is formed between the detected pattern data generation circuit 16 and the comparator 18 to supply data through a pattern data memory 30. In the comparator 18, as shown in FIG. 2, a comparator for data comparing method of die-to-die (die-to-die comparator) 18a and a comparator for data comparing method of die-to-database (a die-to-database comparator) 18b are disposed. Reference pattern data (first reference pattern data) obtained by the reference pattern data generation circuit 22, and detected pattern data obtained by the detected pattern data generation circuit 16 are entered to



the die-to-die comparator 18a. The currently detected pattern data and second reference pattern data, which is the formerly detected pattern data temporarily stored in the pattern data memory 30 and is read out after predetermined conditions are established, are entered to the die-to-database comparator 18b.

The comparator 18 has two inspection modes: a die-to-database data comparison method which compares the detected pattern data with the first reference pattern data, and a die-to-die data comparison method which compares the detected pattern data with the second reference pattern data. One of these methods is carried out, or both are simultaneously carried out.

The pattern data memory 30 has a capacity to store a detected image of a total stripe length during stripe inspection. Additionally, it is configured to enable, even in the middle of pattern storage during the stripe inspection, concurrent execution of reading a first half pattern of the stripe which has been stored and writing a latter half pattern of the stripe which is newly obtained.

In the drawing, a reference numeral 23 denotes an autoloader, 24 a control circuit of an autoloader, 25 a controller of a table, 26 a control circuit of an autofocus, 27 a piezoelectric device, 28 a laser measuring device, 31 a floppy disk, 32 a CRT, and 33

a printer.

In such a configuration, the computer 20 stores designed pattern data used for forming a certain number of plates to be inspected. When inspection of a given  
5 plate (exposure mask) is instructed by an apparatus operator or certain programs, the computer 20 starts analysis of relevant designed pattern data, further extracts the chip arrangement data, the number of chips, a chip dimension, a repeated pitch etc., upon  
10 discriminating that the mask is formed of a plurality of chips and the die-to-database comparator can be used in combination with the die-to-die comparator. The computer 20 further sets data necessary for a parameter table of software, a register of hardware etc., and  
15 enters in an operation mode which uses the die-to-die data comparison method and the die-to-database data comparison method in combination.

FIG. 3 is a conceptual view showing a configuration of a pattern written on a general mask to  
20 be inspected. Two identical chips are written on one mask 50 (photomask 11), and a repeated pattern is written in the chip in units of so called cell. The pattern formed on the mask 50 is divided into a peripheral pattern 51 and a main pattern 52. The main  
25 pattern 52 is further divided into a logic control part (peripheral circuit) 53 and a memory part (cell) 54. In the drawing, reference numeral 55 denotes a chip

datum point, and 56 a cell datum point.

In the case of such a two-chip configuration, the chips are generally arranged in a relation where they are in parallel in an X or Y direction. In the case of  
5 4 or 6 chips formed on one mask, though not shown, the chips are repeatedly arranged in X and Y directions, to form a matrix.

The embodiment will be described by way of a case where identical chips A are arranged on two places in a longitudinal direction of a stripe to be inspected.  
10 For convenience, a first chip is represented as A, and a second chip as A'. If the mask is formed of a plurality of chips as described above, upon discriminating that the die-to-die data comparison method can be used in combination with the die-to-  
15 database data comparison method, database inspection is first carried out from a start point of the chip A while a sensor image is stored from a stripe head in the pattern data memory 30. The database inspection is  
20 carried out up to a boundary point between the chips A and A', which is pre-extracted and determined. However, in a latter half of the stripe after the boundary point, the die-to-die data comparison method is used in combination with die-to-database data  
25 comparison method to compare a detected image subsequently fetched from the sensor with the pattern image of the first half of the stripe which has been

stored in the pattern data memory 30.

In this case, it is necessary to accurately detect the coordinates of the start point of the chip A and the boundary point between the chips A and A', and to  
5 so accurately align chips (dies) as necessary for the die-to-die data comparison method.

In the pattern inspection apparatus of the embodiment, a step of specifying a coordinate is automatically executed by utilizing features on data  
10 description configuration of the designed pattern data. On the contrary, in a conventional method, an operator has carried out the step by using observation optics such as a microscope to visually check the mask to be inspected.

15 As shown in FIG. 4, the designed pattern data has a hierarchy structure with respect to chip and cell definitions. In this example, as shown in FIG. 3, an arrangement coordinate of a chip is defined as a left bottom point of the chip. In such a data structure,  
20 from the situation of the arrangement coordinate, two-place arrangement of the chips on the mask can be read by detecting "datum point coordinates 1 of chip A" and "datum point coordinates 2 of chip A".

Thus, the following coordinates are automatically  
25 recognized without teachings of the operator, that is, a start coordinate of the die-to-database inspection and fetching of an image of the chip A at the same

time, a start coordinate of the die-to-die inspection  
at the boundary point of the chip A' executed in  
parallel with the die-to-database inspection, and  
a finish coordinate of one stripe inspection after  
5 an area of the chip A' is finished.

The comparator 18 detects defects in the area of  
the chip A' by both of the original die-to-database  
data comparison method and the die-to-die data  
comparison method. However, it is advised to apply  
10 defect discrimination conditions and threshold levels  
of defect or not to the two data comparison method,  
independently. Thus, defects common to the plurality  
of chips caused by writing abnormalities due to a  
writing device can be detected by the die-to-database  
15 data comparison method, while defects caused by line  
width abnormalities of micropatterns or the like,  
detection of which are supposed to be difficult in the  
die-to-database data comparison method, can be detected  
by the die-to-die data comparison method. As a result,  
20 it is possible to realize detection performance which  
has been impossible by a conventional single function  
apparatus of the die-to-database data comparison method  
and the die-to-die data comparison method.

The idea of the embodiment to automate the  
25 coordinate recognition when the die-to-database data  
comparison method and the die-to-die data comparison  
method are used in combination is not limited to the

aforementioned case of the two-chip arrangement, and can be applied to a mask where three or more repeated arrangements of the chips are defined. Further, the repeated feature extraction is not limited to the longitudinal direction of the stripe in the inspection step, and can also be applied to the arrangement where the chips are arranged by a plurality of times in a step direction, in such a manner that the apparatus is automatically operated by similarly fetching arrangement information, a start position and a finish position in the stage stepping direction from the designed pattern data.

Next, the defect inspection operation of the embodiment will be described in more detail.

The hierarchy structure of the database for the plate to be inspected according to the embodiment is composed of three stages: minimum unit figures, cells each of which is an aggregate of individual figures, a chip of an aggregate of cells etc. One or a plurality of chips may be arranged in the mask. In the case of arranging a plurality of chips, similar chips may be arranged on a plurality of places, or different chips may be arranged on a plurality of places.

Inspection by the die-to-die comparison method of the embodiment targets the similar chips arranged on the plurality of places. Since a plurality of chips

are arranged on one mask, and the chips are compared with one another, "die" and "chip" are the same in the case of the die-to-die data comparison method. The chip can be divided into a peripheral circuit part and a main pattern part. However, to compare the two chips with each other, discrimination between the peripheral circuit part and the main pattern part is not necessary, and the entire chip is recognized as a repeated shape to be processed.

10           The database used for inspection is designed pattern data used for writing. Prior to inspection, a step shown in FIG. 5 is carried out to read the number of chips, a chip dimension, a repeated chip pitch, or the number of cells, a cell dimension, 15           a repeated cell pitch etc., and to write the information in the data file of inspection conditions to define the operation of the inspection apparatus.

          The data file of inspection conditions describes, for each execution of inspection, a defect threshold 20           of the inspection, an illumination method of transmitted/reflected light, a magnification mode of inspection etc. An inspection execution program is operated by referring to the file together with the database. FIG. 6 shows an example of the data file of 25           inspection conditions. As shown in FIG. 6, inspection conditions are enumerated item by item to be specified for each inspection. If a flag is ON on an inspection

mode of die-to-die combined with die-to-database  
(ON/OFF), i.e., die-to-die inspection should be carried  
out in combination with die-to-database inspection, the  
inspection apparatus starts previous data preprocessing  
5 for extracting repeated features of a die, analyzes  
start/finish coordinates of each die, and writes  
coordinate values in a predetermined part of the data  
file of inspection conditions, i.e., lower 4 lines of  
FIG. 6.

10 In addition to the data file of inspection  
conditions, the inspection execution program refers to  
a parameter table of software provided on the computer,  
and an information table to be written in a register of  
the inspection apparatus hardware etc. Upon setting  
15 them, the inspection apparatus enters an operation mode  
of using the die-to-die comparison method and the  
die-to-database comparison method in combination.

FIG. 7 is a time chart explaining an inspection  
step for one stripe in the inspection apparatus of  
20 the embodiment. It is assumed that in the exemplified  
chip configuration of the mask to be inspected, two  
chips are arranged in the longitudinal direction  
(X direction) of the stripe, as shown in FIG. 3.  
Further, the exemplified stripe is beforehand specified  
25 to be subjected to die-to-die inspection, and even  
before a die extraction step prior to the start of  
inspection, the execution of die-to-die inspection is



to be determined.

An interval to enable die-to-die inspection is from time t4 to t5. Die-to-database inspection is carried out over the entire time period t1 to t6.

5 The die-to-database inspection is started from the time t1 and, at and after the time t2, a detected image of a die 1 is also fetched into the pattern data memory 30. When the inspection reaches so called dicing region, which is a boundary of the chips (dies)  
10 at the time t3, the fetching into the pattern data memory 30 is completed. To carry out the die-to-die inspection at the time t4, a detected pattern image of a die 1 is read from the pattern data memory 30, and input to the die-to-die comparator 18b.

15 FIG. 8 is a time chart explaining an inspection step of one stripe to be inspected when three chips are arranged in the longitudinal direction (X direction) of the stripe in the inspection apparatus of the embodiment.

20 Die-to-database inspection is carried out over the entire period of time t1 to t6. The die-to-database inspection is started from the time t1 and, at and after the time t2, a detected image of the die 1 is also fetched into the pattern data memory 30. When the  
25 inspection reaches so called a dicing region, which is a boundary of chips (dies), at the time t3, the fetching into the pattern data memory 30 is completed.

To carry out the die-to-die inspection with a die 2 at the time t4, the previous detected pattern image of the die 1 is read from the pattern data memory 30, and input to the die-to-die comparator 18b. At the time  
5 t5, the die-to-die data comparison between the die 2 and the die 1 is finished. To carry out the die-to-die inspection between the die 3 and the die 1 at the time t6, the previously detected pattern image of the die 1 is read again from the pattern data memory 30, and  
10 input to the die-to-die comparator 18b. At the time t7, the die-to-die comparison between the die 3 and the die 1 is finished.

Thus, it is a feature of the embodiment that the die-to-database data comparison method and  
15 the die-to-die data comparison method are used in combination during detected data fetching of the stripe to be inspected, while there is a slight time difference between the timing of starting the die-to-database data comparison and the timing of  
20 carrying out the die-to-die data comparison.

Further, for example, in order to deal with a case where it takes time to generate designed pattern data from a database, the die-to-database data comparison method may be executed not in synchronization with the  
25 detected data fetching of the stripe to be inspected. That is, as shown in a time chart of FIG. 9, at time t1, pattern fetching of one stripe to be inspected and

designed pattern data generation from the database are started, and a stripe pattern is entirely read into the pattern data memory 30. It is assumed that the pattern fetching of one stripe to be inspected is finished at  
5 time t6, but designed pattern generation from the database carried out at the bit pattern data generation circuit 21 takes time, e.g., until time t8. The designed pattern data generated from the database at the bit pattern data generation circuit 21 is obtained  
10 by generating a figure pattern from figure data, and its pattern data can be temporarily stored in a stripe pattern data memory present in the bit pattern data generation circuit 11.

Since the pattern fetching of one stripe to be  
15 inspected is finished at the time t6, the die-to-die data comparison can be started at the time t7. The die-to-database data comparison is started at time t9 after the designed pattern data generation from the database is finished, and finished at time t11. When  
20 the designed pattern data is read from the database, since the designed pattern data generation has been finished, the period of t9 to t11 is shorter than that of t1 to t8.

Thus, according to the embodiment, by reading the  
25 arranged state, the number, the dimension and the repeated pitch of repeated pattern areas necessary for the die-to-die data comparison method from the designed

pattern data to automatically fetch the inspection area, it is possible to eliminate operator's operation mistakes and setting variance in the die-to-die data comparison method. Thus, operability and defect  
5 detection performance of the apparatus can be improved. As a result, production yield of an exposure mask, a semiconductor device and an LCD is improved, and product returns are reduced to lower total production costs.

10 (Second Embodiment)

The first embodiment has been described by way of example where the repetition of a relatively large area called a chip is extracted and the repetitive features are automatically reflected on the operation of the  
15 apparatus. Incidentally, as exemplified by the layout of the mask in FIG. 3, repeated description of a plurality of units (cells) is often included in one chip. For example, in the case of a memory device called D-RAM or S-RAM, it is usual that a number of  
20 cell structure portions for memory holding are arranged, and wiring patterns of signal input/output to these cells are arranged on the periphery of the cell portion.

For such repeated cells in the chip, the  
25 inspection apparatus can automatically read the repeated cells from the database described in the hierarchy structure, and fetch it into the operation

conditions thereof. That is, the arranged state, the number, the dimension and the repeated pitch of cells are read from the information described regarding the repeated cells in FIG. 4.

5           The example of the first embodiment is about the repetition of the relatively large area called a chip. However, the apparatus of the second embodiment described here inspects relatively many cells of a repeated structure by a die-to-die data comparison  
10           method.

          When a stripe 58 similar to that shown in FIG. 10 is inspected, a fetched image of a first cell in a chip A is inspected by a die-to-database data comparison method while being stored in a pattern data memory 30  
15           and, for a second cell of the chip A, a die-to-die data comparison method is used in combination with the die-to-database data comparison method to compare the fetched image with the first cell pattern previously stored in the pattern data memory 30.

20           As in the previous embodiment, according to the present embodiment, during the period of combined use of the comparison methods, a comparator 18 detects defects by the original die-to-database data comparison method and the die-to-die data comparison method, and  
25           it is advised to apply defect discrimination conditions and threshold levels of defect or not different from each other to the two methods, independently.

The operation is continued for the stripe 58 by using the die-to-die data comparison method in combination with the die-to-database data comparison method to compare the cells with each other, at and  
5 after the second cell of the chip A. However, a portion which is not a cell, e.g., a boundary portion between the chip A and the chip A' of FIG. 10 is inspected only by the die-to-database comparison method.

10 Extraction of coordinates is carried out by a computer 20. When inspection of a certain plate (exposure mask) is instructed, the computer 20 starts analysis of relevant designed pattern data. If it is determined that a feature such as a cell repeated  
15 definition is present in a relevant mask, data description has a hierarchy structure, and the die-to-die data comparison method can be used in combination with the die-to-database data comparison method, the arranged state, the number, the dimension and a  
20 repeated pitch etc., of cells are further extracted. Additionally, the computer 20 sets necessary information in a parameter table of software and a register of hardware, and the processing enters an operation mode which uses the die-to-die data  
25 comparison method and the die-to-database data comparison method in combination.

Similarly to the previous embodiment, the

extraction of repeated features is not limited to the longitudinal direction of the stripe in the inspection step, but cells may be repeatedly arranged in a step direction. Even within a stripe width, if small cells  
5 are repeatedly arranged in the step direction, the die-to-die data comparison method can be operated in a 2-dimensional matrix in the step direction and the longitudinal direction of the stripe in units of the small cell pattern.

10 (Third Embodiment)

The first and second embodiments have been described by way of example where the plurality of chips are arranged on one mask. However, one chip may be arranged on the mask. The following two cases are  
15 conceivable for one chip arrangement:

(1) as shown in FIG. 11, one mask is designed to have only one chip; and

(2) a plurality of chips are originally arranged on a mask, but a hierarchy structure is destroyed in  
20 the preprocessing step of inspected data, and thus the mask is described as one chip by appearance.

In the case (1) of original one mask=one chip designing, as described above with reference to the second embodiment, the die-to-die comparison method may  
25 be carried out in units of cell by paying attention to the repeated cells.

However, in the case (2), the data structure shown

in FIG. 4 has no descriptions of "datum point coordinates 1 of chip A" and "datum point coordinates 2 of chip A". This state is generated when a hierarchy structure is flatly developed in order to carry out  
5 certain preprocessing for the entire designed pattern data, such as pattern dimension resizing (processing for adjusting pattern line width) or adding a very small figure pattern to the original pattern for an optical proximity correction (OPC).

10 Depending on the preprocessing, there are a case where a chip hierarchy structure is developed while the repeated cells are left intact, and a case where flat operations are conducted to develop the repeated cells and figure descriptions in a cell are arrayed. To  
15 process such data by the apparatus, the following work enables combined use of the die-to-die comparison method which uses the repeated pattern and the die-to-database comparison method as in the first embodiment. One such work is to restore repeated cell information  
20 by extracting repeated figures on the grounds that figures having similar figure codes and side lengths repeatedly appear in the designed pattern data, and pitches thereof are equal, etc. Other work is to restore repeated information per chip by detecting  
25 presence of repeated cell aggregates.

In the designed pattern data used for database inspection, a figure is represented by a set of



a figure code, a figure position and a figure side length as shown in FIG. 12. Since the designed pattern data contains accumulation of such figures, arrangement of figures where only figure positions are different,  
5 but figure codes and side lengths are similar can be extracted by searching for this figure data description.

Repeated figures extracted by the method includes both of repeated cells and repeated chips in the  
10 chip/cell configuration shown in FIGS. 3 and 4. Thus, a difference in regularity between a repeated cell cycle and a repeated chip cycle is read, and information of the die-to-die comparison method based on the repeated chips is extracted and reflected on the  
15 operation of the apparatus.

If the repeated cells are determined, the apparatus is set for die-to-die data comparison between the cells. These instructions are defined beforehand as apparatus parameters, or included in inspection  
20 conditions to be given to the apparatus.

#### (Fourth Embodiment)

The third embodiment has been described by way of a method which also analyzes the figure data of the destroyed hierarchy structure by the inspection  
25 apparatus, and repeatedly extracts and restores the information. However, in place of figure data analysis, the designed pattern data may be converted

into a figure image to be temporarily stored in the pattern data memory or the like, and a method of extracting a feature of the figure image may be used to restore a feature of a repeated pattern.

5           According to the embodiment, as shown in FIG. 13, a stripe pattern data memory 63 which can store a figure image of one stripe is prepared for a bit pattern data generation circuit 21. The bit pattern data generation circuit 21 further comprises a figure data memory 61 to which the designed pattern data is  
10           entered, a figure data bit pattern data generation circuit 62 which generates a figure pattern image from the figure data, and a repeated feature extraction circuit 64 which extracts repeated pattern features.  
15           The figure image generated by the figure data bit pattern data generation circuit 62 is stored in the stripe pattern data memory 63. For the figure data of one stripe stored in the stripe pattern data memory 63, the repeated feature extraction circuit 64 analyzes  
20           presence, the number and the pitch of repeated figures by a pattern matching method.

          The pattern matching method holds a partial area of detected pattern data fetched into the pattern data memory 63 as a template, and scans the entire pattern  
25           data memory to compare the template with the fetched detected pattern. When the template is held, a coordinate of the template is also recorded.

A stripe area is scanned 2-dimensionally and, when a pattern coincident with the template is detected, its coordinate is recorded.

Thus, even if the designed pattern data having no  
5 hierarchy descriptions is used as the inspection  
database, presence of a repeated pattern equivalent to  
a chip or a cell can be estimated from the coordinate  
recorded by the template scanning. A result of the  
analysis is sent to a computer 20, not shown, which  
10 carries out an operation of using in combination the  
die-to-die comparison method using repeated cells or  
chips and the die-do-database comparison method similar  
to those of the first to third embodiments.

The pattern generation by the bit pattern data  
15 generation circuit 21 is originally designed to  
generate inspection reference data for database  
inspection. Thus, during inspection, a dimension of  
one generated pixel is set very small in order to  
equally generate very small pattern shapes of the  
20 inspection reference data. However, if the purpose is  
to analyze the repeated feature of the figure pattern  
as in the case of the embodiment, since precision equal  
to that for the original inspection is not required,  
a dimension of one generated pixel is set slightly  
25 large to generate a rough pattern image, which creates  
no practical problems.

According to the embodiment, when the stripe

pattern formation and the analysis to analyze an image  
are completed, a dimension of one pixel is returned to  
an original value for original database inspection, and  
inspection is started from a predetermined inspection  
5 start position.

Furthermore, a stripe position for the  
aforementioned analysis may be selected to be near  
a chip center in consideration that a chip peripheral  
portion has no repeatedly described cells as shown in  
10 FIG. 11. However, if a chip configuration is a  $2 \times 2$   
matrix, the center portion may reach a gap area called  
a peripheral pattern or dicing region having no  
repeated cells, creating a possibility of impossible  
analysis of a repeated configuration. Thus, it is  
15 practically effective to analyze the stripe in a  
position slightly shifted from the vicinity of the  
center.

(Fifth Embodiment)

In place of the repeated pattern feature  
20 extraction executed after the generation of the image  
data from the designed pattern data of the fourth  
embodiment, repeated pattern feature extraction may be  
carried out by using detected pattern data.

FIG. 14 is a block diagram showing a main part  
25 configuration of a pattern inspection apparatus  
according to a fifth embodiment of the present  
invention. A feature extraction circuit 74 similar to

that of the fourth embodiment is disposed to extract a repeated feature from detected pattern data temporarily stored in a pattern data memory 30.

As shown in FIG. 14, pattern data fetched from a sensor is written in the pattern data memory 30, and data of one stripe is held. Based on the pattern data, the repeated feature extraction circuit 74 analyses presence, the number, and the pitch etc., of repeated figures by a pattern matching method. A result of the analysis, not shown, is sent to a computer 20, and an operation is carried out which uses in combination the die-to-die comparison method and the die-to-database comparison method using repeated cells or chips as in the case of the first to fifth embodiments.

Thus, according to the embodiment, in the case of executing repeated feature extraction based on the detected pattern data, a method may be employed which does not set a dimension of one pixel as small as in the case of the fourth embodiment, reduces a magnification rate in comparison with an original optical magnification, fetches a rough image, and extracts repeated cells or chips from the image.

(Modification Example)

The present invention is not limited to each of the foregoing embodiments. Detection to obtain detected pattern data is not always limited to transmitted light, and reflected light may be used.

Both of the transmitted light and the reflected light may be simultaneously used. Further, the number of photoelectric conversion parts may be plural.

5 A light source used for inspection is not limited to light, and an electron beam can be used as shown in FIG. 15. If the electron beam is used for the light source, secondary electrons may be detected in place of the reflected or transmitted light. In FIG. 15, a reference numeral 13' denotes an electron gun, 14'  
10 electron optics, and 15' a secondary electron detector.

An inspected sample is not limited to a photomask. The present invention can be applied to defect inspection of a very small pattern formed on a semiconductor substrate or a liquid crystal substrate.

15 As described above, according to the present invention, by reading the arranged state, the number, the dimension and the repeated pitch of repeated pattern areas necessary for the die-to-die comparison method from the designed pattern data or the detected  
20 pattern data within a predetermined range to automatically fetch the inspection area, it is possible to prevent operator's operation mistakes and setting variance in the die-to-die comparison method. Therefore, it is possible to improve operability and  
25 defect detection performance of the apparatus.

The embodiments of the present invention are summarized as follows.

(1) For the automatic fetching of the inspection area, presence of a plurality of repeated pattern areas is detected from the layout information contained in the designed pattern data, and the arranged state, the number, the dimension, and the repeated pitch of the repeated pattern areas are read.

More specifically, if data having a repeatedly described chip is contained in the designed pattern data in the mask inspection area formed of a plurality of chips, a method is employed which extracts a margin of each chip and a peripheral circuit region from the data, and reads the arranged state, the number, the dimension and the repeated pitch of chips necessary for the die-to-die comparison method to automatically fetch them into the operation conditions of the apparatus.

(2) For the automatic fetching of the inspection area, a predetermined pattern range is defined as a cell based on the hierarchy structure of the designed pattern data, the cell repeated description is extracted from the designed pattern data by using the cell repeated description to detect presence of the repeated cell, a start position and a finish position of the repeated cell are determined, presence of a plurality of starts/finishes thereof is detected, and the arranged state, the number, the dimension and the repeated pitch of the repeated cells are read.

More specifically, even if a plurality of chips

are not arranged in a matrix, by using the hierarchy  
structure description of the designed pattern data for  
inspection, a mechanism which extracts a repeated  
pattern (cell) of a proper size, and a method which  
5 reads the arranged state, the number, the dimension and  
the repeated pitch of cells to enable comparative  
inspection of cells by the die-to-die comparison method  
from the extracted information to automatically fetch  
them into the operation conditions of the apparatus are  
10 employed.

(3) For the fetching of the inspection area, image  
data is generated in the pattern data memory based on  
the designed pattern data, image filtering is carried  
out to extract a repeated feature by pattern matching,  
15 and the arranged state, the number, the dimension and  
the repeated pitch of repeated subchips in one chip are  
read.

More specifically, even if the designed pattern  
data for inspection is not described in a hierarchy  
20 structure, upon instruction for repeated inspection, an  
image pattern which becomes an inspection reference is  
generated prior to real inspection, the pattern  
matching technology is applied to extract presence of  
repeated patterns, and a method which reads the  
25 arranged state, the number, the dimension and the  
repeated pitch for comparative inspection of detected  
pattern data by the die-to-die comparison method from



the detected information to automatically fetch them into the operation conditions of the apparatus is employed.

5 (4) For the automatic fetching of the inspection area, image filtering is carried out to fetch a detected image of one stripe at a certain position of the sample, the detected image of one stripe is stored, and a repeated feature of the detected image is extracted, formation of a plurality of chips to be compared and inspected by the second comparator on the 10 plate to be inspected is detected, and the arranged state, the number, the dimension and the repeated pitch of repeated subchips in one chip are read.

Alternatively, repeated cells in the chip may be 15 detected, and the arranged state, the number, the dimension and the repeated pitch of cells may be read.

More specifically, even if no designed pattern data for inspection is prepared, a sensor image of one stripe is fetched at a certain position of the mask, 20 the image of one stripe is stored, the pattern matching technology is applied to detect presence of repeated patterns, and a method which reads the arranged state, the number, the dimension, the repeated pitch etc., of cells to enable comparative inspection of cells by the 25 die-to-die method from the detected information to fetch them into the operation conditions of the apparatus is employed.

(5) Both of die-to-die inspection and die-to-database inspection are executed for the same detected pattern area.

5 According to the present invention, if there is repeated chip description in the layout information contained in the designed pattern data, the arranged state, the number, the dimension and the repeated pitch of chips necessary for the die-to-die comparison method are read from the layout information, and  
10 the inspection area is automatically fetched in the die-to-die comparison method. Thus, even without teachings of the operator, defect inspection can be carried out by calibration, alignment, and the die-to-die comparison method. Therefore, operator's operation  
15 mistakes and setting variance in the die-to-die comparison method can be prevented to enable improvement of operability and inspection accuracy.

Even if there is no layout information, it is possible to read the arranged state, the number, the  
20 dimension, the repeated pitch etc., of chips necessary for the die-to-die data comparison method from the hierarchy structure of the designed pattern data. Moreover, if there is no hierarchy structure in the designed pattern data, by saving the image data roughly  
25 converted based on the designed pattern data in the pattern data memory, and extracting the repeated feature by the image filtering, it is possible to read

the arranged state, the number, the dimension, and the repeated pitch of repeated subchips in one chip.

Furthermore, without using the designed pattern data, by fetching the detected pattern data of one  
5 stripe at a certain position of the plate to be inspected, and carrying out the image filtering to extract the repeated feature of the detected image, it is possible to read the arranged state, the number, the dimension, the repeated pitch etc., of repeated  
10 subchips in a chip.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments  
15 shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.